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A STUDY OF INDIVIDUAL DIFFERENCES IN IMPROVEMENT

BY

EDWARD VAN LANDEGEND

A THESIS SUBMITTED FOR THE DEGREE OF
MASTER OF ARTS

UNIVERSITY OF WISCONSIN

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A STUDY OF INDIVIDUAL DIFFERENCES IN IMPROVEMENT

I. Introduction.

The general subject of improvement of mental functions by practice was first investigated quantitatively and experimentally in 1897-1899. Bryan and Harter (1) were the pioneers in this field and their study of the improvement of a mental function by a study of learning to send and receive telegraphic messages constitutes the first contribution of importance in this field. Since that time others have been active in making similar investigations of improvement in other traits particularly in relatively simple functions. The results of all these contributions have been summarized by Thorndike (2) as showing the following general facts:

1. Improvement is apparently universal.
2. There is a very rapid rate of improvement under experimental conditions.
3. There are marked differences in the amount and rate of improvement in different functions.
4. There are marked individual differences in the amount and rate of improvement.

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(1)

(2) THORNDIKE, E.L: Psychology of Learning, pp. 150-151.

This last result, viz., that There Are Marked Individual Differences in The Amount and Rate of Improvement, has been made the subject of this study. Special investigation was begun on this phase of the problem of improvement by Thorndike (1) in 1908. Before reviewing these special studies a brief summary of the types of exercises employed in the exact study of learning will be given.

History

Types of Activities Studied.

In the study of improvement of mental functions it is essential that the exercises be of the same uniform type, if differences in amount of work produced, time taken, or, errors made are to be accurately measured. Since many of the more complex activities in human behavior are individualized, products involving very complex situations and responses would be extremely difficult of measurement, if it were possible to measure them at all. Consequently, in a study of the improvement of a function with practice effort has been concentrated almost exclusively on the simpler elementary processes. Investigators have approached the problem from various standpoints and a number of types of exercises have been used. These exercises vary from activities which are elementary and of a reflex character, to relatively more complex operations involving a considerable

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(1) THORNDIKE, E. L: Psychology of Learning, pp. 150-151.

number of associations and abstractions. A brief summary of the various types of exercises used in determining the degree and rate of improvement in mental functions follows.

Partridge (1) constructed a device to determine the amount of learning in control of the winking reflex. A glass plate was adjusted before the eye and a rubber hammer was made to strike the glass directly in front of the eye. The subject was to inhibit winking coincident with the strike of the hammer on the glass plate. Here we find measurement in improvability studied in the sphere of reflex action. Wells (2) tested adults in the rate of tapping in order to get at factors in improvement after periods of practice. The exercise consisted of tapping a telegraph key as rapidly as possible for a period of thirty seconds and repeating ten times a day, alternating hands. In this exercise, also, the situation and the response were reduced to a simple type. Attention was focused on a single isolated activity. No especial skill whatever is exhibited in this response and it is incessantly a measure of the amount of nervous energy of the individual.

Swift (3) used the method of tossing two balls in the air with one hand. Since the balls were of unequal weight and diameter the arm motion involved a number of joints,

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(1) PARTRIDGE, G. E: Experiments Upon the Control of the Winking Reflex. Am. Journal of Psychology, Vol. XI., 1900, pp. 244-250.

(2) WELLS, F. L: Normal Performance in Tapping Test, A.J.P., Volume 19, pp. 437-483.

(3) SWIFT, E. J: Studies in the Psychology and Physiology of Learning. A.J.P., Vol. 14, pp. 201-251.

muscles and tendons, and while this exercise is somewhat more complex than tapping, still it must be placed in the category of relatively simple reactions.

Whitley(1) Klein(2) Wells(3) and others tested improvement by means of marking out a's on a printed page. This test involves perception, attention and choice of movements of a somewhat more complex sort.

Lueba and Hyde(4) conducted a series of experiments on students who translated English prose into German, and who also translated into English script prose which had previously been translated into German script. Since the accuracy of the work was constant only the speed was measured. The processes involved in this exercise were very much more complex than in any of the previous ones.

Munn(5) Starch(6) and Dearborn(7) employed a substitute test which required the subjects to rewrite a system of letters in another key. The exercise involves relatively simple processes of associative substitution.

---

(1) WHITLEY, M.T: An Empirical Study of Certain Tests for Individual Differences. Archives of Psychology, No. 19.

(2) KLEIN, L. W: Some Experimental Evidence on the Doctrine of Formal Discipline. Bulletin of the State Normal School, Duluth, Minnesota, February, 1909.

(3) WELLS, F. L: The Relation of Practice to Individual Differences. Am. Jl. of Psychol. Vol. 23, pp. 75-88.

(4) LEUBA, J.H. & HYDE, W: Studies from the Bryn Mawr College Psychological Laboratory. An Experiment in Learning to Make Hand Movements. Psy. Rev. Vol. 12, pp. 351-369.

(5) MUNN, A.F: The Curve of Learning. In Studies of Development and Learning. ed. by E. A. Kirkpatrick. Archives of Psychology, No. 12.

(6) STARCH, D: Periods of Work in Learning. Journal of Educational Psychology. Vol. 3, pp. 209-213.

(7) DEARBORN, W. F: Experiments in Learning. Journal of Educational Psychology, Vol. I, pp. 373-388.

Swift and Schuyler (1) and Book (2) studied improvement in typewriting by sight and touch methods respectively. The fixed situation and uniform responses in this exercise place it on a relatively simple order.

Ebert and Meumann (3) studied improvement in adults by means of learning non-sense syllables. Winch followed a similar course with consonants.

Thorndike (4) Starch (5) and Whitley (6) investigated improvement in mental multiplication.

The above partial resume is given to emphasize the types of exercises which have been pursued in approaching the problem of determining increments of improvement after periods of practice. They all fall into a common category of reaction characterized by simplicity, definiteness, uniformity. Owing to the highly organized character of the individual subjects, the varying original tendencies, and environmental influences, the responses must be reduced to a simple type. In the higher processes it is more difficult to compare accurately products

---

(1) SWIFT & SCHUYLER: The Learning Process, Psychological Bulletin, Vol. 4, pp. 307-310.

(2) BOOK, W. F.: The Psychology of Skill: With Special Reference to its Acquisition in Typewriting. University of Montana, Publications in Psychology. Bulletin No. 53, Psychological Series No. 1.

(3) EBERT. E. & MEUMANN, E: Ueber Einige Grundfragen der Psychologie der Uebungsphanomene im Bereiche des Gedachtnisses. Archiv. für gesamte Psychologie, Vol. 4, pp. 1-232.

(4) THORNDIKE, E.L: The Effect of Practice in the Case of a Purely Intellectual Function. Am. Jl. Psy. Vol. 19, pp. 374-384.

(5) STARCH, D: Transfer of Training in Arithmetical Operations. Jl. of Ed. Psychol. Vol. 2, pp. 306-310.

(6) WHITLEY, M.T: An Empirical Study of Certain Tests for Individual Differences. Archives of Psychology, No. 19.

since they reflect personalities more markedly and have become more highly individualised. Most of these experiments have been performed on adults, consequently, it is even more necessary that the exercises be of an elementary character in order to avoid the influences of habituations.

Methods.

The problem of measuring improvement with practice is beset with difficulties. Let us suppose that a group of individuals are subjected to practice for a period of time and let us suppose, as is always the case, that the individuals show differences at the outset and make varying gains throughout the practice period. How can the amount or rate of improvement be most accurately shown? How can the individual differences in capacity at the outset be fairly compared and indicated and how can the gains be made commensurable and comparable?

There are two main methods in vogue in the measurement of improvement with varying derivatives of these.

Percentile Method. In the percentile method the initial period(or any preceding period)may be taken as a base and the percentage of improvement can be determined. Thus the rate of gain of a single individual can be compared at stated intervals, and the rates of gain of different individuals also may be compared.

This method has some objectional features and often leads to absurdities. In case the initial score is 0 any gain

(as 1) in the next score must be represented by infinity. Also the student with an exceptionally low score in the initial period may be represented as making the greatest gains which often is contrary to a sane interpretation.

One individual in the fourth grade has an initial score of 5 and a final score of 40 problems. By the percentile method he will have gained 700%, and another individual in the same group has an initial and a final score of 13 and 51 problems respectively, or a percentile gain of approximately 290%. The latter, however, has apparently made the greatest gain.

The Gross Gain method takes cognisance only of concrete results. It regards all elementary products of a uniform character and no differentiation is made in the relative value of the results whether they be at the initial or at the final extreme of the scale. Since each increment of ability varies in accordance with its relative position the gross gain method does not state conditions as they actually exist, and, consequently, a subjective interpretation of the computations is essential in order to get to the key of the true situation. This method has been used throughout the present work.

The method here used is a slight modification of the Gross Gain Method. The initial deviation of the group or individuals from the class average is taken and compared with the deviation in the final period.

Different Phases of Improvement Compared.

In every experiment, regardless of the nature of the test, each subject occupies his own peculiar, individual position. This is one characteristic fact of all tests - that there is absolutely no uniformity in the subjects, but that they are by heredity and training as diverse as there are members under examination. Even in the manipulation of a machine, a typewriter for example, in which none of the subjects has had any previous training they stand at various levels in initial efficiency since they have all had different types of experiences in coordinating certain groups of muscles which will be called into play in practice on the typewriter, and which will thereby cause various ranks of efficiency at the very outset and before the first performance. Coupled with these acquired variable capacities are the inherent capabilities, which also render uniformity in the initial efficiency an impossibility.

The fact of varying initial efficiency, while not a disqualifying obstacle, is nevertheless, a serious barrier to securing an accurate measure of relative improvement. Every subject is performing within his own relatively fixed limits, and in case one individual has already attained considerable proficiency - due to well functioned neurones which will be called into action in the exercise in question - his

gross gains and also his percentile gain will appear relatively small, and he will soon approach his approximate limit.

Another individual may have a low initial efficiency due to a lack of coordinating ability in the proper bonds, and consequently, his periodic improvements are likely to show striking results both in the percentile and in the gross gain method. Thus we find considerable disparity in the initial efficiency which exerts a marked influence on later results and renders comparable computations difficult. To environmental influences which cause varying degrees of efficiency at the initial trial must be added inherited capacity. A subject with unusual native ability which gives him a high score in the early trials will likely make good improvements continuously regardless of a high initial efficiency.

The disparity in improvements between these two subjects can logically be accounted for by unlike initial efficiency and while this condition must be constantly met it need not render deductions valueless.

The subjects in a test should be grouped as nearly as possible about a common median in present capacity, and this present ability should be as far as possible from the psychological limit. In case some of the subjects have approximately approached their limit they will simply

continue their performances, and while their gains may be commensurate with their present standing, the manifestations of progress so far as gross gains or percentile gains are concerned will be practically nil, and they (while theoretically advancing) will appear to be stationary at their respective limits, while the other subjects are rapidly catching up to their standing. Under such circumstances few deductions can be made from comparative results.

Furthermore, it should be borne in mind that every change in the score from the initial efficiency to the physiological limit designates a varying degree of improvement in each individual. In general an improvement at the initial end of the scale is represented by greater numerical values than an improvement near the limit. Example - A runner is able to cover 100 yards in 11 seconds when he goes into training. In a comparatively short time as a month he reduced his time to 10 seconds. In the next month he further reduces his time to nine and four-fifths seconds. No comparison can be made between the improvements of these two consecutive periods on the basis of numerical values. It would be absurd to argue that since in the first month the gross gain was five times the gross gain in the second month, and that he, therefore, made a greater gain during the first period. It is highly probable that the gain of one-fifth of a second in the second month was a greater achievement than the numerical gain of five times that amount in the previous

month. It is, therefore, evident that a change in the record during one period of practice cannot be interpreted to mean that an absolutely corresponding change has resulted in the degree of improvement.

Again, the fourth grade student enters upon the work of the grade with an initial efficiency of five examples per unit of time. Tests at bi-monthly periods show the following record for the year in problems worked correctly, 5, 10, 13, 15, and 16. A superficial deduction from the above score may run as follows - that the greatest improvement was made during the first period of practice. Since this is the period of greatest gross gain (5) and also the greatest percentile gain (100%) the evidence based solely on the numerical basis, and without any reference to the physiological limit would appear to be sound. However, during the initial period of practice attention is paid to the lowest order of habits. There is a concentration of mental effort to the automatic perfection of the cooperation of elementary bonds. During the later stages the work is carried on by complex processes, and attention is more and more diverted from elementary connections to the manipulation of groups. In other words a higher order of habits is being established and since relationships are becoming more intricate a greater amount of time is required in establishing habituations. The amount of physical and mental effort involved in making this shift from a single order of

responses during initial periods of practice to a more highly organized system may be considerable, and still the actual, concrete results may be incommensurate to the amount of energy expended. Thus, the effort has resulted not so much in production as in the building up of potentiality. Improvement follows different lines and becomes of a different type. While the rate of improvement diminishes actual improvement in mental power may continue at a relatively rapid rate, and the problem is to establish relations between these variables. We can determine increments of ability only by outward manifestations and consequently all estimates of improvement must proceed along the line of concrete results.

In the period between the third and fourth practice (in the problem under consideration) we find that the results were 15 in both scores. If we interpret this score solely by the gross results the rate of progress will be nil. But there doubtless has been forming a new organization of habits of a higher order which makes possible a further gain in the next period.

A Review of the Work Done.

The data thus far advanced have direct bearing on mental functions in general. The aim was primarily to discover whether mental functions are improvable, and if so, whether this applies to all individuals and to all functions. The results of the experiments enumerated above tend to point with scarcely an exception to an answer in the affirmative. Consequently, with this question of the improvability of mental functions disposed of we can proceed to the real issue, viz. - a study of individual differences in improvement. Do all individuals improve with like acceleration? Do individuals who have a high initial efficiency improve at the same rate relatively as those of a low initial efficiency? Is there a physiological limit of attainment, and if so, is it general, and what are its determinants? Is the rate of improvement in the various functions of a single individual constant, and is this a general characteristic?

Experimental work in this field has been done by Thorndike,(1) Starch,(2) Wells,(3) Kirby,(4) Donovan,(5) and Hahn.(6) Thorndike(1) in an experiment in addition used nineteen university students as subjects- eight men and eleven women. He found that with equal periods of practice the students who had the highest initial standing made the largest gains with equal accuracy in the number of problems worked. Thorndike(1) and Donovan(5) performed a similar experiment on twenty-nine fourth grade students. Two-minute practice periods were given twice daily for three weeks. Records of this experiment show that the average number of examples worked correctly rose from $2\frac{3}{4}$ to $4\frac{1}{2}$ examples per minute.

Kirby(4) performed similar experiments in addition with 700 fourth grade students. He gave his subjects 75 minutes of practice and compared the results of the first 15 minutes with the last 15 minutes, which gives the result of 60 minutes of practice. This experiment was performed under school-room conditions. The results showed an average initial

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(1) THORNDIKE, E. L.: Practice in Addition. Am. Jl. of Psy. Vol. II, pp. 483-486.

(2) STARCH, D.: Transfer of Training in Arithmetical Operations. Journal of Educational Psychology, Vol.II,pp.306-310.

(3) WELLS, F. L.: The Relation of Practice to Individual Differences. Am. Jl. of Psy. Vol. 23, pp. 75-88.

(4) KIRBY, T. J.: The Results of Practice under School Conditions. Teachers College, Columbia University Contrib. to Education.

(5) DONOVAN: Improvement in a Practice Experiment under School Conditions. Am. Jl. of Psy. Vol. 24, pp. 426-8.

(6) HAHN. H.H.: Some Results of Practice in Addition under School Conditions. Jl. of Educ. Psy. Vol V. No.2.

score of 31 attempts with 24 right, and a final score of 50 attempts with 37 right- or a gain of over 50% with equal accuracy. He also tested 600 third grade students in addition. Sixty minutes of work was given the students and the score of the first ten minutes was compared with that of the last ten minutes, which allowed for 50 minutes of practice. The results of this experiment showed 40 examples attempted with 37 right in the initial period compared with 73 examples attempted and 70 correct in the final period, i. e. the amount of work done was almost doubled with equal accuracy.

He also tested 503 pupils of the fourth and fifth grade in division. Scores covering 15 minutes were taken before and after a period of 45 minutes of practice. He found that a gain of from one to three problems was made by 13 individuals, that the modal gain was from 15 to 19 problems, and was made by 141 students and the maximum gain was from 45 to 49 problems and was made by 3 pupils.

Wells (1) used ten adult subjects in performing an experiment in oral addition. One-place numbers were used in vertical columns. The subjects were given 150 minutes distributed over 5 or 6 weeks. The results show that the amount of work was doubled without any decrease in accuracy.

Thorndike, (2) Starch, (3) and Whitley (4) pursued slightly

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(1) WELLS, F. L.: See Page 14.
(2) THORNDIKE, E. L.: See Page 14.
(3) STARCH, D.: See Page 14.
(4) WHITLEY, M. T.: See Page 4.

different methods in working out individual differences of improvement in mental multiplication. Thorndike (1) tested 28 subjects in the mental multiplication of a three-place number by a three-place number. All digits below three were eliminated. An example was exposed for a period sufficiently long for the subject to memorize the figures and was then withdrawn. The individual performed the multiplication without any paper or pencil, and without having the problem before him. It was wholly a mental operation, and the subject was permitted to write the answer only when it was completed. The amount of improvement was based on the scores of the first five examples and the first five of the last six. The records showed that the amount of time required for the last five examples compared to that required for the first five varied from .14 to .70, the median ratio being .42. The amount of practice each individual received varied directly to the number of examples completed, and those who finished the same number of problems received an equal amount of practice. The average college graduate with seven hours of practice on similar examples was found to make an average improvement such that he could do 2½ times as many problems in the last period compared with the first.

Whitley (2) experimented with similar problems in multiplication under a slightly modified procedure. In his

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(1) THORNDIKE, E. L.: See Page 14.

(2) WHITLEY, M. T.: See Page 4.

experiment the problems were exposed throughout the operation. The nine subjects worked three problems a day for a period of twenty days (Sundays excluded). The scores of the first three examples compared with the last three show that the average amount of work done in the last period is from two to two and one-half times as much as in the initial period and of equal accuracy.

Starch (1) tested eight individuals in mental multiplication with 700 examples assigning 50 a day. The problem consisted of the multiplication of a three-place by a one-place number. The records of the number of problems per ten minutes on the first day compared with the number done on the fourteenth day show a gross gain of from 4.8 to 63 with an average gross gain of 32.1 and a percentile gain ranging from 19% to 170% with an average of 112%. The amount of work in the final period was thus more than doubled in comparison to that of the first period.

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(1) STARCH, D. : See Page 14.

Trend of Results in above Review.

All the types of exercises and all the various functions enumerated above indicate conclusively improvement in a function which is exercised with a view toward improvement. This fact has been challenged in a number of exercises such as the discrimination of weights, of pitches, and also in the discrimination of two points from a single point on the periphery, Cases can be accounted for in part at least by the fact that in practice in the discrimination of lifted weights the subject is kept in ignorance of his errors and consequently has no means of correcting his erroneous judgments. If intelligence is given him of the true relations after each judgment and if he can be spurred on by motives to increase his ability of discrimination improvement also in these functions will inevitably result. Whitley (1) bears this out in an experiment on weights. She found that by a single daily practice over a period of 16 days the average error was reduced from 11.1 grams to 6.3 grams.

It has been further argued that there is little or no improvement possible in "visual attention" or "visual apprehension". Experiments along this line, - exposing isolated letters or figures for a brief period and then requiring the subject to record as many of the characters as possible in order to secure his scope of attention - have been performed by Whipple. While his results show no improvement they cannot

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(1) WHITLEY, M. T. : See Page 4.

be taken as conclusive proof as they cover extremely brief periods of practice. His results are based on practice periods including a total exposure of but a few seconds, - a period too brief to expect a marked degree of improvement. If the total exposure were made to cover a period of several hours his data indicates an improvement of double the number of characters apprehended.

Introductory Statement to the Problem.

The material of this study consists of tests in the four fundamental operations in Arithmetic which were given monthly throughout the year, and were furnished by the principal of the Alice School of Hibbing. Minnesota. They were part of a study of the improvement in school subjects throughout the year. Grades 4, 5, and 6 have been studied especially. The Courtis Tests, Series B, which give eight minutes for addition, four minutes for subtraction, six minutes for multiplication, and eight minutes for division were used. Three lists of problems rotated in the monthly tests in order to avoid any possible learning of answers, and thus each list was given after an interval of three months.

For purpose of this study all the examples which were correct in the four fundamental operations were combined and used as the score of the individual for each month. No attention was paid to problems which were incorrectly worked.

The students of the several classes are divided into groups in accordance with their final ability. The final score is used in preference to the initial score since there is a wider range of problems which permits a greater latitude in forming the groups, i.e., in the fourth grade the number of problems ranged from 0 to 13 in the initial score, and from 6 to 51 in the final score. It seems preferable to make this division between the latter figures(6 and 51) and the class is accordingly divided into four groups as follows:

Grade IV.

Group I	40 and over
Group II	30 to 40
Group III	20 to 30
Group IV	below 20

Grade V

Group I	55 and over
Group II	40 to 55
Group III	below 40

Grade VI

Group I	60 and over
Group II	40 to 60
Group III	below 40

The results appear in the Tables and curves in the following pages. Each grade is first presented separately and then some general conclusions are drawn for all the grades.

DEPARTMENT OF MATHEMATICS. Right

FORM M2.

CALCULATION SHEET.

Date ______ Sheet No. ______

Made by ______

Checked by

Refers to Grade 4. ~~Table I summar~~izes the performances of the Fourth ~~Grade~~ pupils.

	initial score	final score	gross gain	INDIVIDUALS initial	final	gain	Average gain
Entire Class.	4.8	26.8	22.0				
Group I	8.6	43.2	34.6	1	48	47	34.6
				13	51	38	
				11	45	34	
				5	40	35	
				13	32	19	
Group II	4.7	32	27.3	9	26	17	27.2
				2	37	35	
				4	32	28	
				4	33	29	
Group III	4.4	21.7	17.3	1	23	22	17.0
				9	20	11	
				6	20	14	
				3	21	18	
				7	28	14	
				0	20	20	
				5	25	20	
Group IV	2.	9.3	7.3	0	9	9	6.6
				4	6	2	
				4x	13	9	

x 2nd month.

Explanatory Statement of Graphs

Plates I, II, III, IV, and V, express the facts graphically:

Plate I. The heavy continuous black line represents the average performances of the class. The narrower continuous lines, in colors, represent the average performances of the respective groups.

Plate II. The heavy continuous black line represents the average performance of the class as in Plate I. The narrower continuous black line represents the average performance of Group I.

The dotted lines, in colors, represent the average performances of the individuals in Group I.

Plate III. The heavy continuous black line represents the average performances of the class as in Plate I. The narrower continuous black line represents the average performance of Group II.

The dotted lines, in colors, represent the average performances of the individuals in Group II.

Plate IV. The heavy continuous black line represents the average performance of the class as in Plate I. The narrower continuous black line represents the average performance of Group III. The dotted line, in colors, represent the average performances of the individuals in Group III.

Plate V. The heavy continuous black line represents the average performances of the class. The narrower continuous black line represents the average performance of Group IV. The dotted line, in colors, represent the average performances of the individuals in Group IV.

This method has been pursued uniformly throughout all the grades.

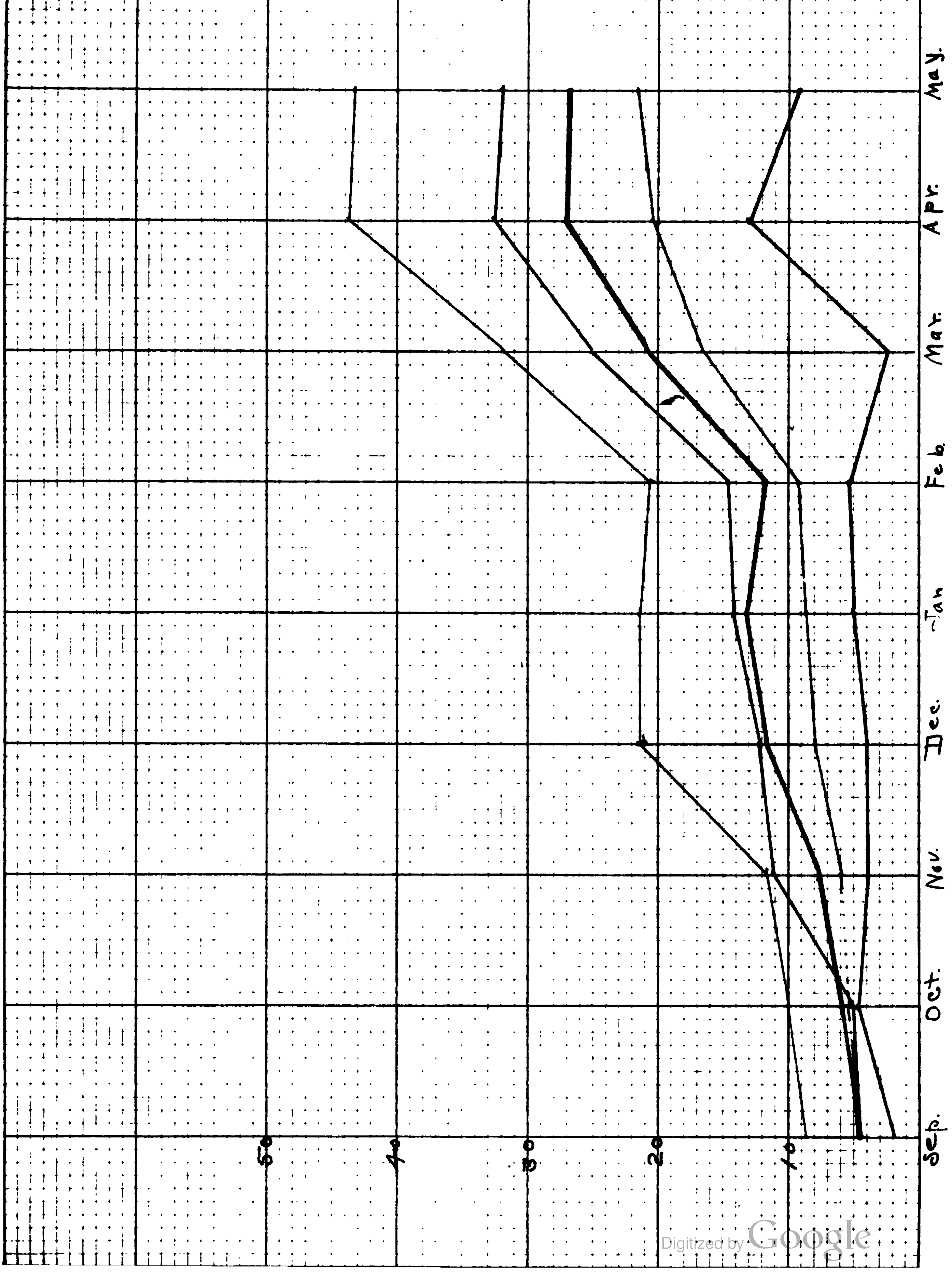
Grade IV

PLATE I

FORM C3

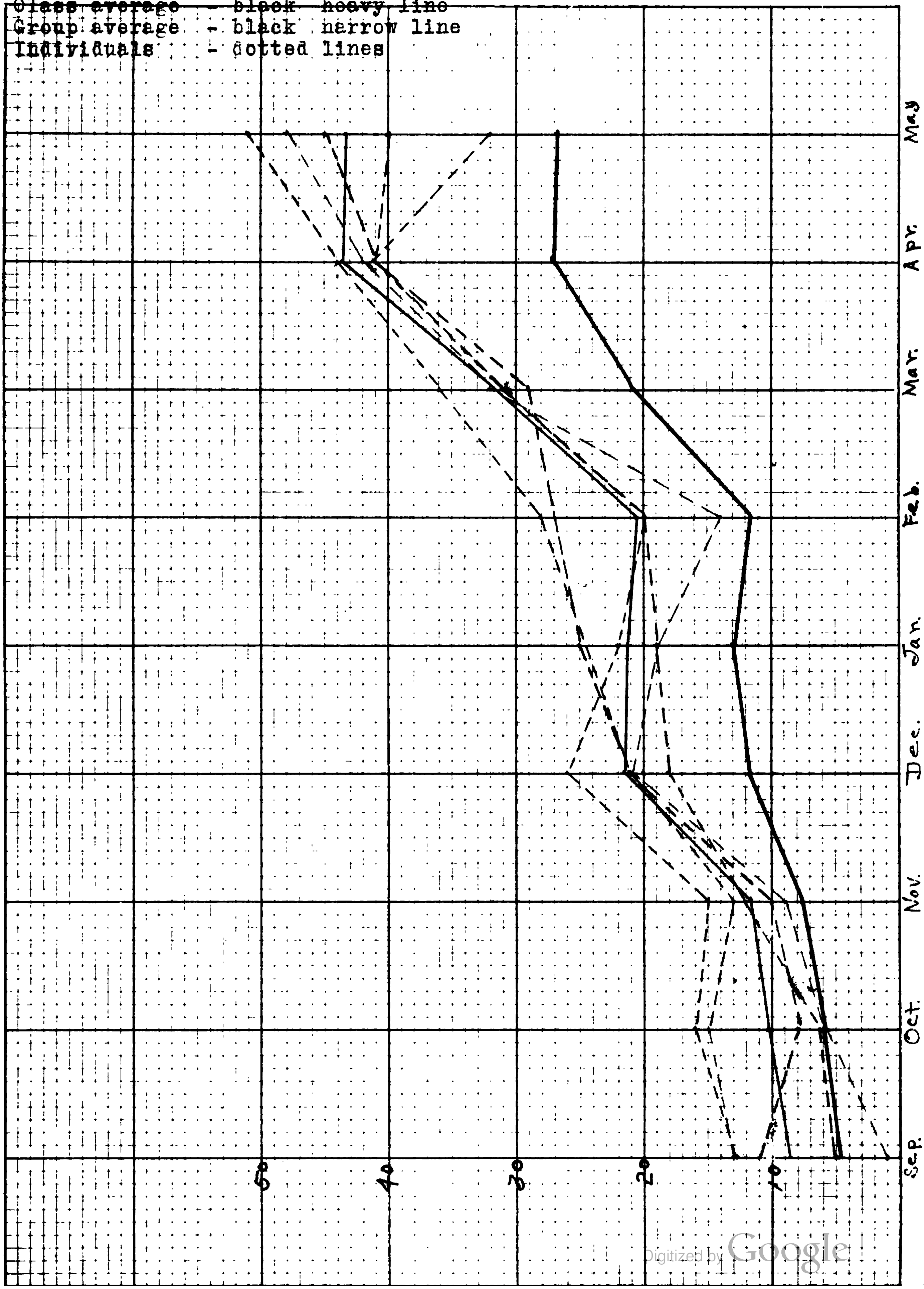
UNIVERSITY OF WISCONSIN

Class average - black
Group averages-



Grade IV PLATE II

Class average - black heavy line
Group average - black narrow line
Individuals - dotted lines

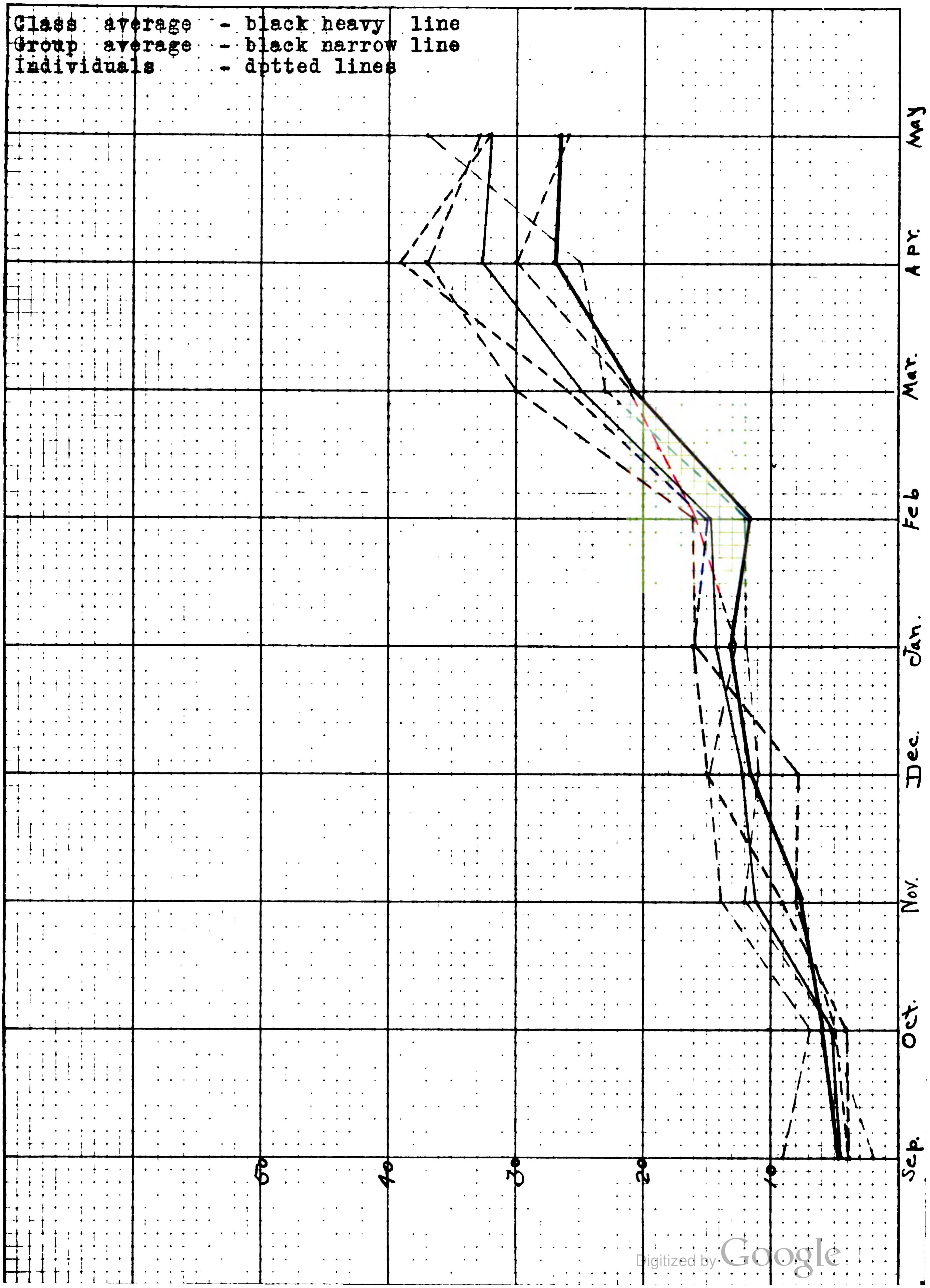


Grade IV

FORM C3

PLATE III

UNIVERSITY OF WISCONSIN

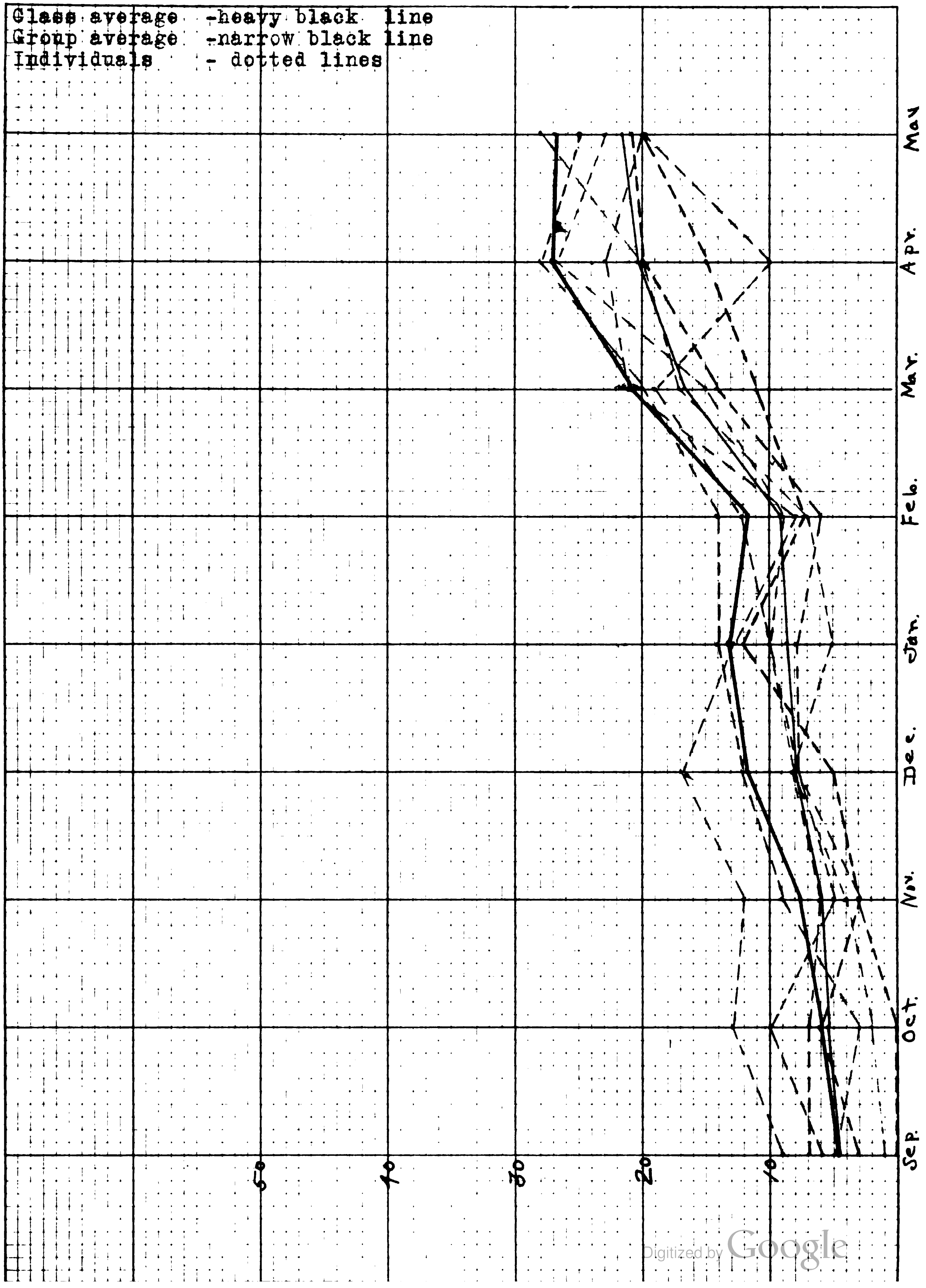


Class average - black heavy line
Group average - black narrow line
Individuals - dotted lines

Grade IV

PLATE IV

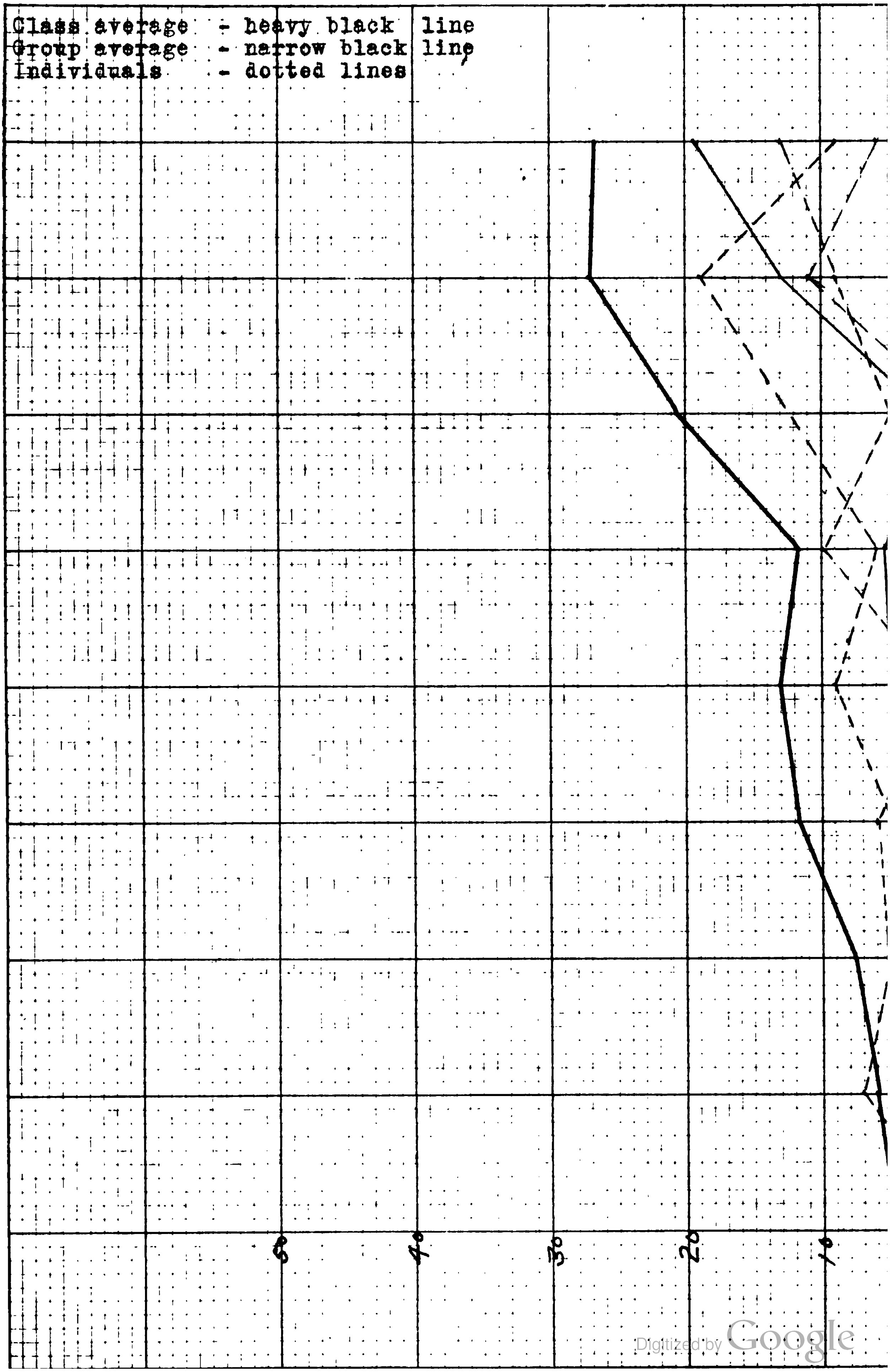
FORM C3 UNIVERSITY OF WISCONSIN



Grade IV
FORM C3

PLATE V

UNIVERSITY OF WISCONSIN



Interpretation of Material.

A Comparison of Group and Class Performances, Grade IV.

The initial performances of Group I as compared with the initial performances of the class show that the difference is 3.8 problems. The final performances of Group I and the entire class show a difference of 16.4 problems, i.e., Group I deviated further from the class average in May than in September by 12.6 problems.

Also a similar comparison of Group II with the entire class average shows that Group II was .1 of a problem below the class average in September and 5.2 problems above the class average in May, or in other words, Group II during the year increased its distance from the average class performance by 5.3 problems.

Comparing Group III and the class averages in respect to the initial and final standing we find that Group III was .4 of a problem below the class average in September and 5.1 problems below the class average in May, or that Group III diverged farther from the class average by 4.7 problems.

A like comparison of Group IV with the normal class performance shows that this Group in the September test was 2.8 problems below the class average, and its record in May was 17.5 problems below the class average. In other words this group diverged more widely from the class average by 14.7 problems in May than in September.

Groups I and II gained greatly through the year while groups III and IV lost greatly relatively to the averages of the class.

It is a noteworthy fact that the divergence throughout the year increases. It is particularly marked in the last three months. The curve of improvement for each group is similar in character. Greatest gain occurs at the close of the year - last four months. It further shows that the greatest deviations (12.6, 5.3, 4.7, 14.7) were made by the extreme Groups I and IV with scores of 12.6 and 14.7 respectively compared with Groups III and II with 5.3 and 4.7 problems respectively, i.e., the two groups representing more nearly the average performance of the class progressed uniformly and show a variation of less difference from the class average than do the extreme Groups. Thus, the greatest variation lies with the highest and lowest Groups of pupils. The brightest pupils have advanced with positive acceleration the slowest Group pupils have progressed with a negative acceleration.

A Comparison of Groups

The difference in scores between Group I and each of the following Groups, II, III, IV in the initial test in September were, 3.9, 4.2, 6.6 respectively, and the difference between Group I and Groups II, III, and IV in the final standing are II.2, 21.5, 33.9. This shows that Group I was further from Group II by 7.3 problems, from Group III by 17.3 problems, from Group IV by 27.3 problems. That is Group I increased its lead over Group II by 7.3 problems, over Group III by 17.3 problems, over Group IV by 27.3 problems.

Similarly, Group II suffered a loss of 7.3 problems with Group I, but gained over Group III by 10 problems, and over Group IV by 20 problems.

Group III was out stripped by Group I by 17.3 problems, by Group II by 10 problems, but gained over Group IV by 10 problems.

Group IV was surpassed by Groups I, II, III with the following scores, 27.3, 20, and 10 problems respectively.

A comparison of the initial and final scores of the various Groups shows that there is a marked tendency for the respective Group average to diverge as illustrated in Plate I.

The Group with the highest initial score has made the largest gross gain. The Group with the second

highest initial score has made the next largest gross gain, and the third Group has made the next largest gross gain. The Group with the lowest initial score has made the smallest gross gain.

The progress of each Group has been along fairly definite and uniform lines of cleavage, and instruction has tended to widen the gaps between the respective Groups as the academic year advanced. Whether the teacher gave her maximum attention to the stronger Groups it is impossible to say, but results evidently point to the fact that the slowest Group profited but little from a year's exposure to arithmetical stimulation.

The pupils of this grade are not properly classified and for the promotion of maximum efficiency and the elimination of waste both on the part of the teacher and also in regard to every individual member of the class a re-classification is absolutely necessary in order to give the teacher a fair opportunity to teach and in order to give to each pupil the recognition due him.

A Comparison of Individuals

Group I.

The maximum initial difference between individual members of Group I is 12 problems, the maximum final difference is 19 problems.

This shows that also within the Group the same tendency holds true for individuals as for the Group, viz. the

individual members diverge more widely at the end than at the beginning. However, in comparison with the Group deviations the amount of divergence is negligible, and it is surprising how closely the various members of the Group stay together in a fairly uniform and comparatively limited zone. In one test the maximum difference between individual pupils is but 3 problems and in two other scores it is but 6 problems. With but a single individual exception in one month this Group advances above the class average throughout the school year.

Group II

The September test registers the maximum initial difference between individual members in Group II as 7 problems, and the maximum final difference as 11 problems. As in Group I the individual members of the select Group still tend to diverge in accomplishment tho it is within relatively narrow limits. The individual members of this Group remain very close together through most of the year. For three months the scores of all members are within 4 problems of less. With few exceptions the members of this Group advance above the average of the class.

Group III

The maximum initial difference between individual members of Group III is 9 problems, and the maximum final difference is 8 problems. In general the members of this Group do not hold together very closely and they are never nearer each other than 8 problems, and they are as far apart

as 18 problems in one score. The individuals of thie Group do not advance with uniformity, but progress is irregular and erratic.

Group IV

The maximum initial difference between individual members of Group IV is 4 problems and the maximum final difference is 7 problems. As is characteristic of the other Groups with the possible exception of Group III, which converges by one problem, the members of Group IV become more widely separated as they continue on in the year's work. The members of this Group follow a relatively narrow zone, and the maximum variation between members ranges from 3 to 10 problems. This Group shows frequent fluctuations in positive and negative progress, and each member shows a lack of steadiness and balance. It is a singular fact that but one member rises in two consecutive tests, and here in each case by a single problem. This is the only oasis which distinguishes the Group. Another individual holds the level at 5 problems for two consecutive months - all other scores without a single exception show alternations upwards and downwards through the year with clock-like precision.

General Summary for Grade IV

I. The divergence between the Groups and the class averages tend to increase continually throughout the year, with a particularly marked tendency to an increase in divergence during the last three months of the year.

2. Greatest deviations were made by the extreme Groups.

3. The lowest Group makes but very slight gain throughout the year and relatively loses greatly.

4. The Group with the highest initial score has made the largest gross gain. All Groups uniformly follow this rule.

5. Each Group follows a fairly uniform line of cleavage, and the gaps between the Groups increase continuously.

6. Apparently, brightest pupils profit most and slowest pupils profit least.

7. The average number of negative accelerations of the four Groups is as follows: Group I, one and four-fifths; Group II, 2; Group III, two and one-seventh; and Group IV, three and one-third problems.

8. Not a single individual passed through the year without at least one negative acceleration.

DEPARTMENT OF MATHEMATICS. Table 2.

FORM M2.

CALCULATION SHEET.

Date ____________ Sheet No. ________

Made by ____________

Checked by ____________

Refers to Rights Grade 5.

For explanatory statement on graphs see page 21.

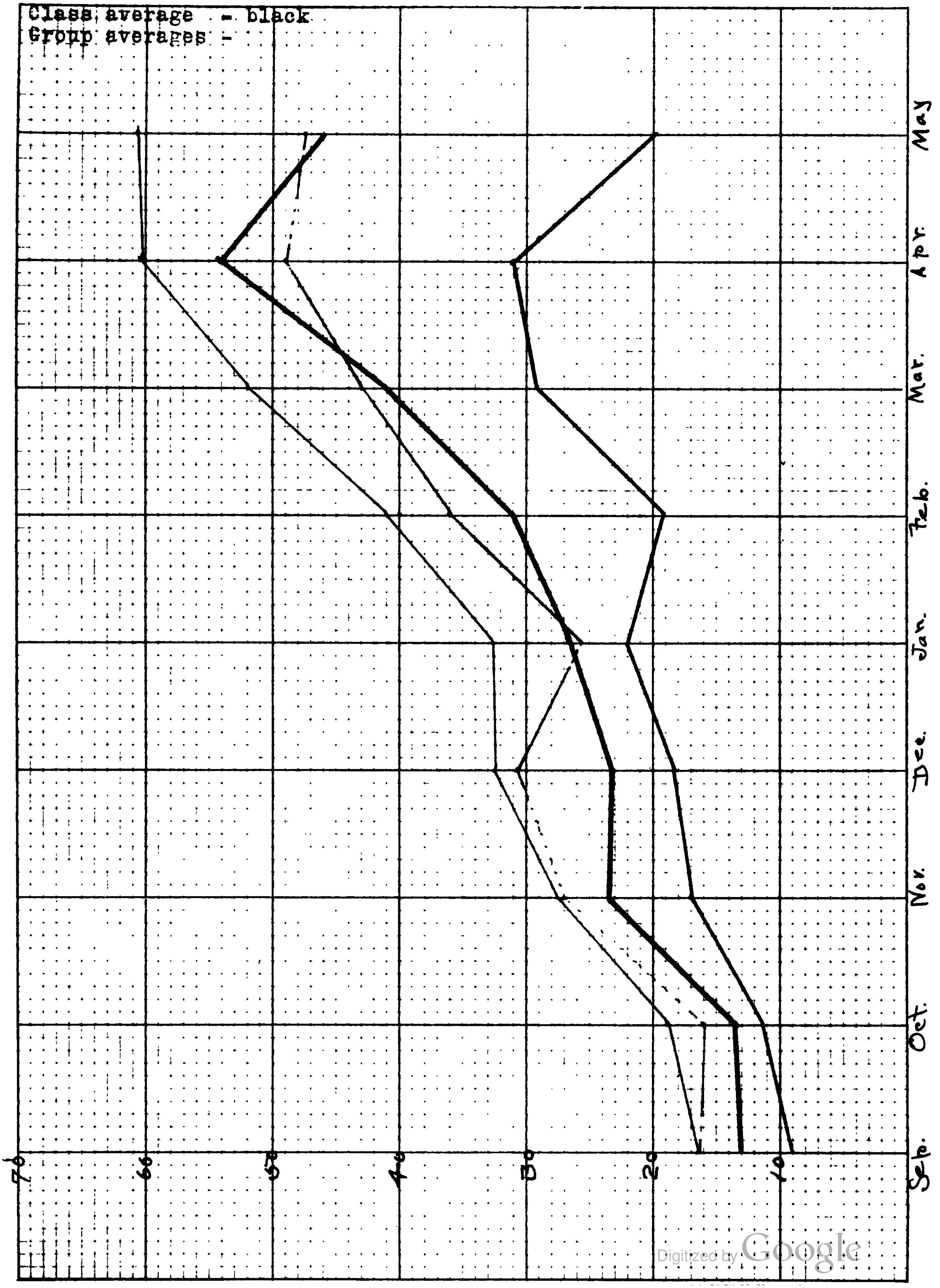
	initial score	Final score	gross gain	Individuals initial	Final	gain	Average gain
Entire Class	13.	45.9	32.9				
				20	62*	42	
				9	64	55	
Group I	16.6	60.7	44.1	8	60	52	44.5
				28	63	35	
				18	56	38	
				11	44	33	
				19	42*	23	
Group II.	16.6	47.5	30.9	18	39	21	29.8
				17	51	34	
				18	56	38	
				12	37*	25	
Group III	9.	20	11	8	37*	29	23.3
				7	20	13	

Grade V

PLATE I

FORM C3

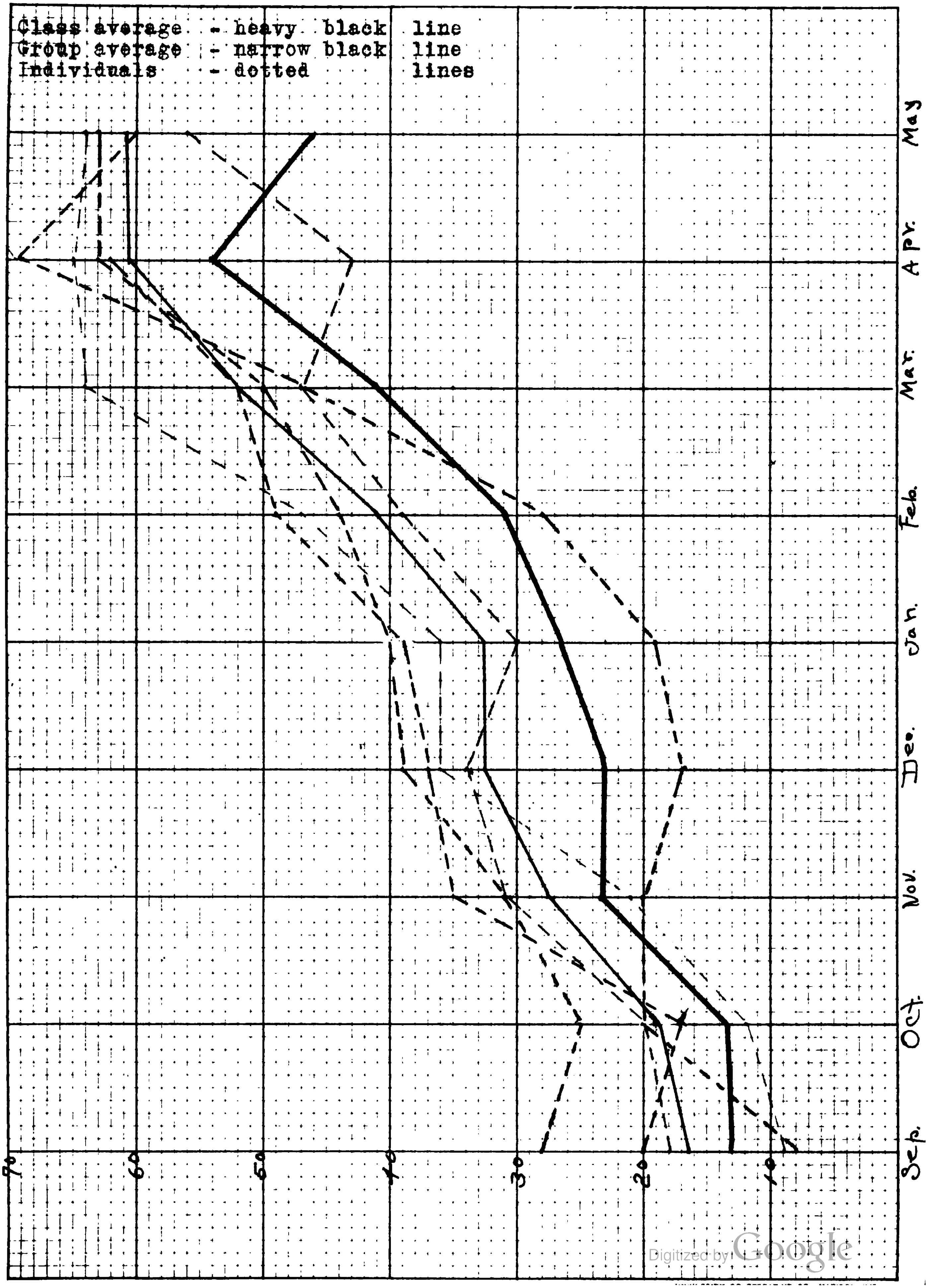
UNIVERSITY OF WISCONSIN



Grade V

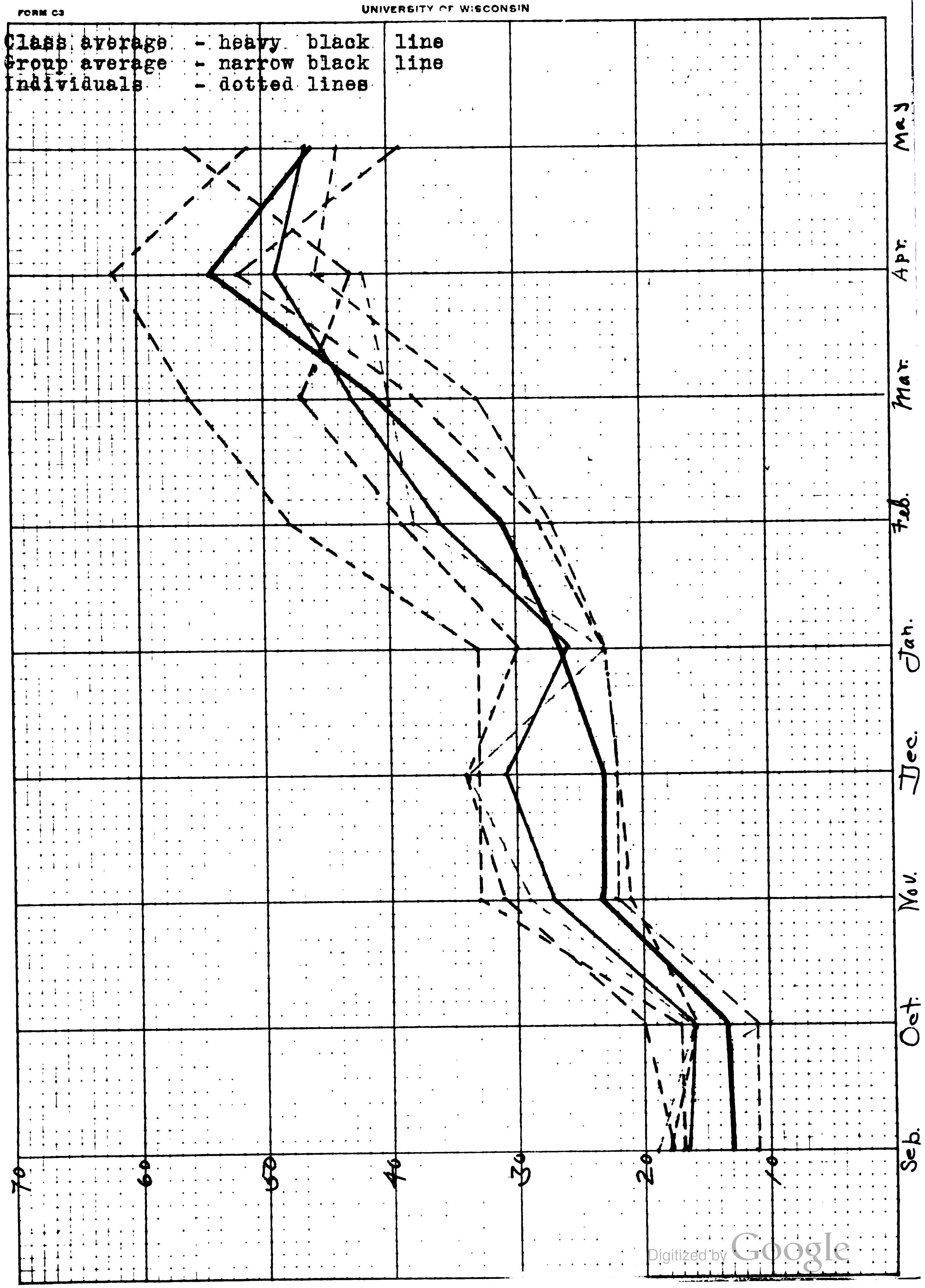
PLATE II

FORM C3
UNIVERSITY OF WISCONSIN



Grade V

PLATE III

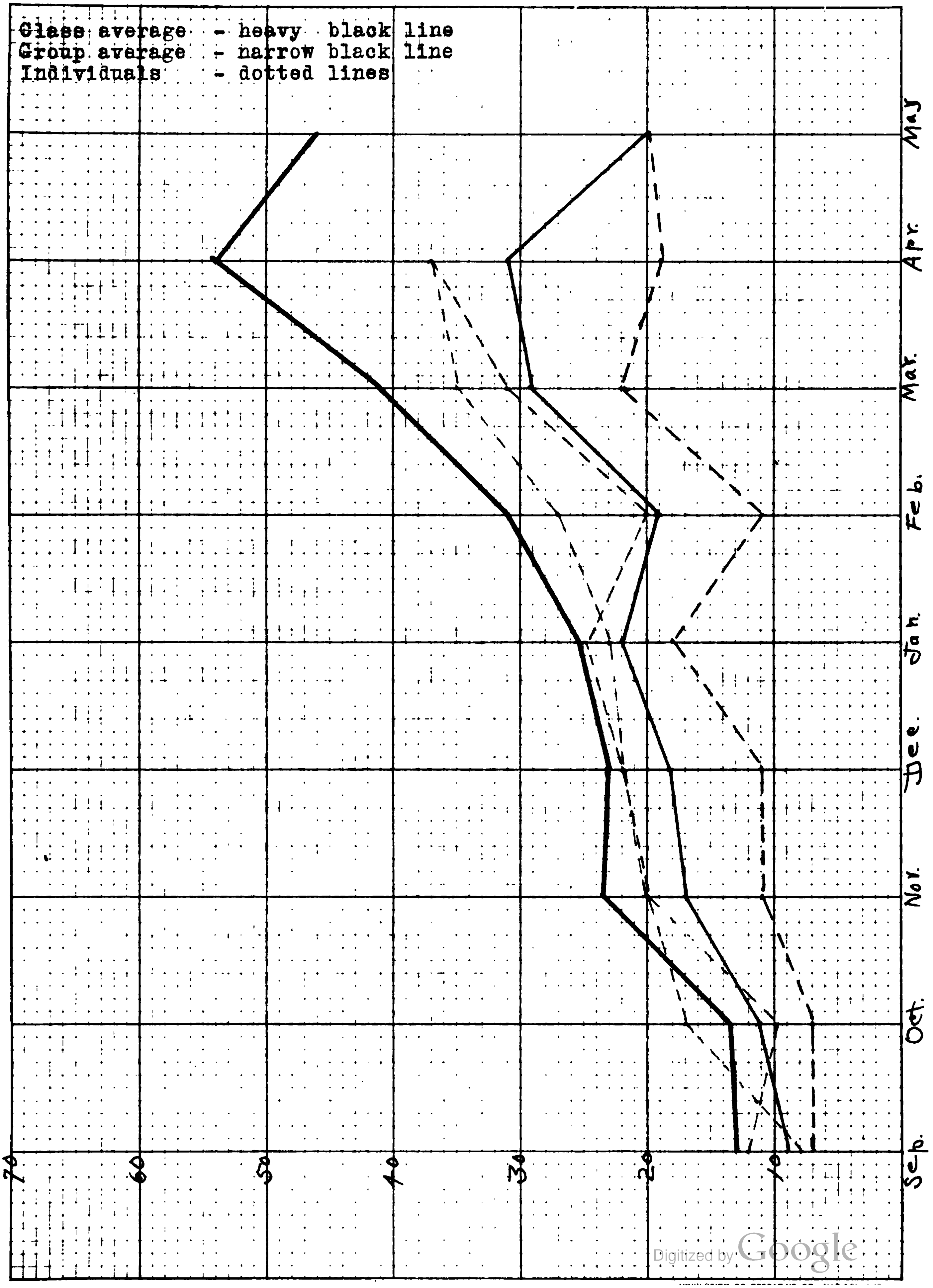


Grade V

PLATE IV

FORM C3

UNIVERSITY OF WISCONSIN



Grade V.

Interpretation of Material.

A Comparison of Group and Class Performances.

The initial performance of Group I is 16.6 problems, that of the class is 13 problems; the final performance of each is 60.7 and 45.9 problems respectively, i.e. Group I increased its distance from the class average by 11.2 problems. The Group was nearest the class average in the initial performance, and from this point onward it diverges considerably throughout the school year. In the final month when the class average drops this Group shows further possibilities.

The initial and final performances of Group II compared with those of the class average show an initial difference of 3.6 problems and a final difference of 1.6 problems. In other words, Group II approached nearer the average of the class by 2 problems. This is expected since the class is divided into three groups and Group II represents the Group average ability. This Group crosses the class average four times and the maximum distance of this Group from the class average is 7.6 problems.

The initial performance of Group III compared with the initial performance of the class shows a difference of four problems. The final performance of this Group and that

of the class shows a difference of 25.9 problems, i.e. Group III diverges from the class average by 21.9 problems. The nearest approach of this Group to the class average is 2.1 problems, and the greatest divergence between this Group and the class average is 25.9 problems which occurs in the final score.

Both the extremes Groups I and III were at greater distances from the class average in May than in September, i.e., the year's work caused a greater divergence of these two groups. The middle Group (III) follows the class average closely and exceeds it in the final stage by but 1.6 problems. This is to be expected since Group II is representative of the average work of the class. As is characteristic of the fourth grade the extreme Groups make the greatest deviations from the class average.

Group I advanced uniformly throughout the year, and relatively to the class average made the greatest gains.

Group III made very slight progress and lost greatly relatively to the class average.

Again in this grade the divergence increases continuously throughout the year and is especially marked in the last half of the year.

The curve of improvement is similar in character. The greatest gain is at the close of the year, - in the last five months.

II. Comparison of Groups.

The initial score of Groups I + II is 16.6, that of Group III 9 problems, and the final scores of these three Groups are 60.7, 47.5 and 20 problems respectively. This shows that the Groups I and II started the years work with equal results, and that Group I which forged ahead after the first month established a lead of 13.2 problems in the final period.

Groups I and II differ by but .4 of a problem in the third test and their maximum divergenc is 13.2 problems which exists in the final score.

Groups I and III have initial performances of 16.6 and 9 problems respectively, and their final scores are 60.7 and 20 problems respectively, i. e. the initial difference is 7.5 problems and the final difference is 40.7 problems or that Group I increased its lead by 33.1 problems.

The initial performances of Groups II and III 16.6 and 9 problems respectively, their final performances were 47.5 and 20 problems respectively, i.e. the initial difference is 7.6 and the final difference is 27.5 problems of Group II increased its lead over Group by 19.9 problems.

By comparing the initial and final scores of these three Groups we find that there is a marked tendency for those three Group averages to diverge during the year's work, and this divergence is greatly accelerated toward the close of the session. The largest gross gain was made by Group I with 44.1 problems and the next largest gross gain is accredited to

Group II. Both these Groups have the same initial score, though Group I assumes the lead in the second test and maintains it throughout the year.

Group III with the smallest initial score registered the least gross gain in the year's study.

As is characteristic of the fourth grade all Groups pursue individual Group paths along divergent courses and thus the members of the several Groups show greater differences in efficiency at the close of the school year.

As in grade four a re-classification of this grade at the mid-year period or quarterly is advisable and would remove the necessity for the teacher to divert her attention over a wide range of individual capacities.

III. A Comparison of Individuals. Group I.

The initial maximum difference between members of Group I is 20 problems, the maximum final difference is 8 problems. While the initial and final scores of this Group show a convergence of the various members, a scrutiny of the figures shows a combination of peculiar circumstances which has caused this apparent convergence. Two members were exceptionally low in the initial score. In the final score all who had been gaining consistently either lost or failed to gain, and the low individual made a tremendous gain of 13 problems, consequently, the convergence. Evidently this May score does not represent the several abilities of the Group as well as does the April record. Since one member is not

Represented in the May score, it seems justifiable to consider the April score as a true final measure of a group. In April the maximum difference between the individual members is twenty-six which shows a divergence of six problems during the eight consecutive months. As in all other groups, here, also we find a tendency of the individual members to diverge during the year's work, though the amount of divergence as in other groups is reduced.

Group II.

In Group II the maximum initial difference between individual members is 8 problems, and the final maximum difference if 17 problems. Thus, the maximum difference between the individual members of the group doubled during the year. Since this is the middle group and representative of the average work of the class, the individual members remain near the class average throughout the year.

Group III.

The members of Group III enter upon the year's work with a maximum difference of five problems and close the year with a maximum difference of eighteen problems. Two members of this group who were separated by a single problem in September are eighteen problems apart in May. Two members who were separated by five problems in September make the same score in May. The characteristic divergence of the individuals in other groups is strongly in evidence in this Group also. The members are nearer together in their work in the initial performance than at any other time.

General Summary for Grade V.

1. All groups show the same tendency (as in Grade IV) to diverge from the class average.

2. The greatest deviation from the class average were made by the extreme groups.

3. The divergence bwtween the groups and the class averages tend to increase throughout the year's work, and this tendency to diverge is especially marked in the last four months.

4. Groups I and II with the highest initial scores have made the greatest gross gain. Group III with the lowest initial score has made the smallest gross gain.

5. Each group pursued a rather definite direction and the gaps between the groups have constantly widened.

6. Slowest pupils apparently profit least.

7. The average number of negative accelerations of the three groups is as follows: Group I, 1.2; Group II, 1.4; Group III, 1.3.

8. No member of the class passed through the year without at least one negative acceleration.

9. The lowest groups makes a very slight gain during the year's work and relatively loses considerably.

Table 3.

DEPARTMENT OF MATHEMATICS.

FORM M2.

Rights

CALCULATION SHEET.

Date ____ Sheet No. ____

Made by ____

Checked by ____

Refers to Grade 6

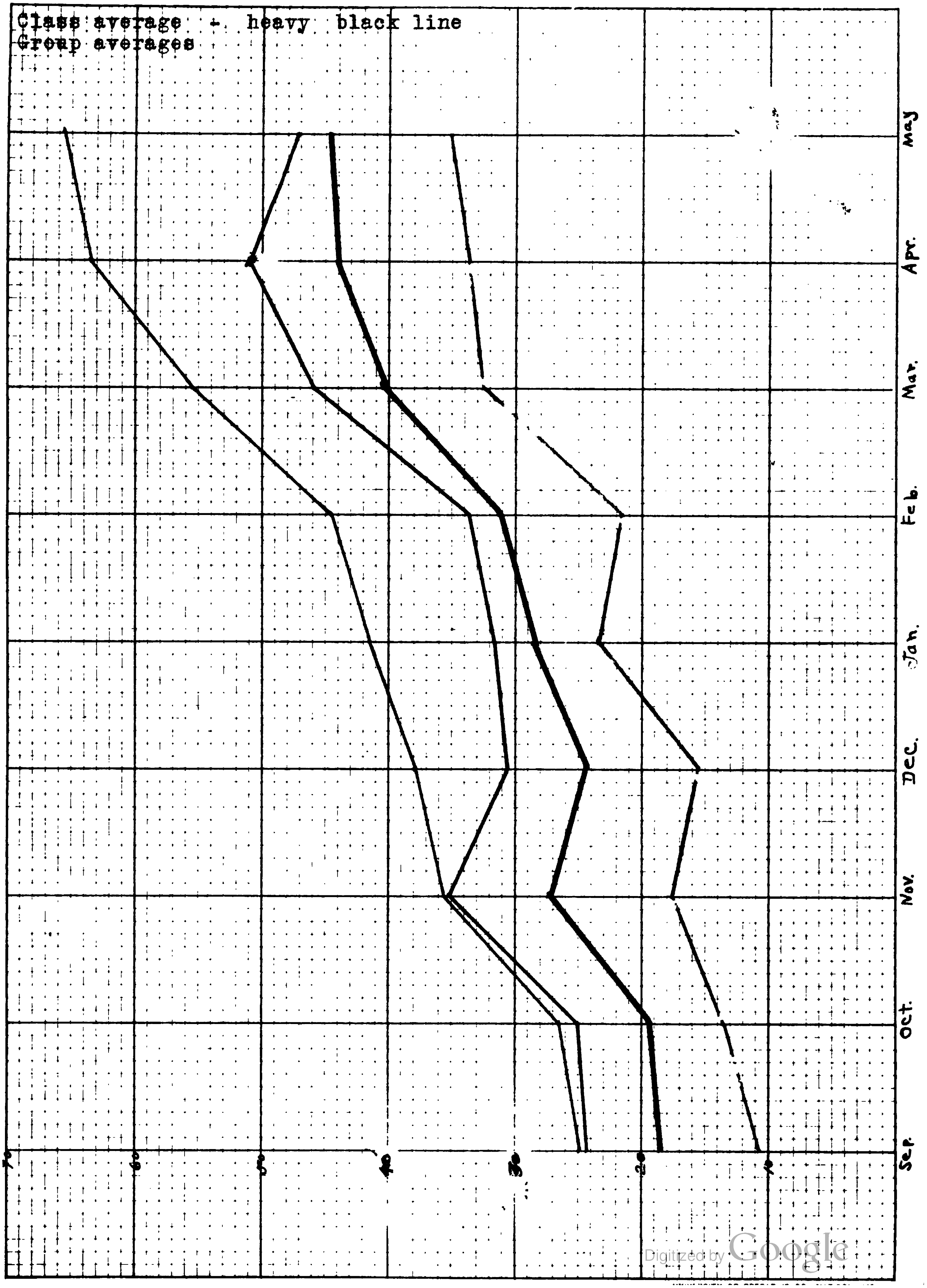
For explanatory statement on graphs see Page 21.

	initial score	Final score	gross gain	individuals initial	Final	gain	average gain
Entire Class	18.8	44.5	25.7				
				30	62	32	
				28	79	51	40.7
Group I	25	65.7	40.7	21	61	40	
				21	61	40	
				20x	42	22	
				34	49	15	23.7
Group II	24.3	47	22.7	23	52	29	
				16	45	29	
				8	38	30	
				13x	23	10	
				12	35	23	23.1
Group III	10.7	35.1	24.4	14	39	25	
				9	39	30	
				16x	37	21	

Grade VI
FORM CS

PLATE I

UNIVERSITY OF WISCONSIN

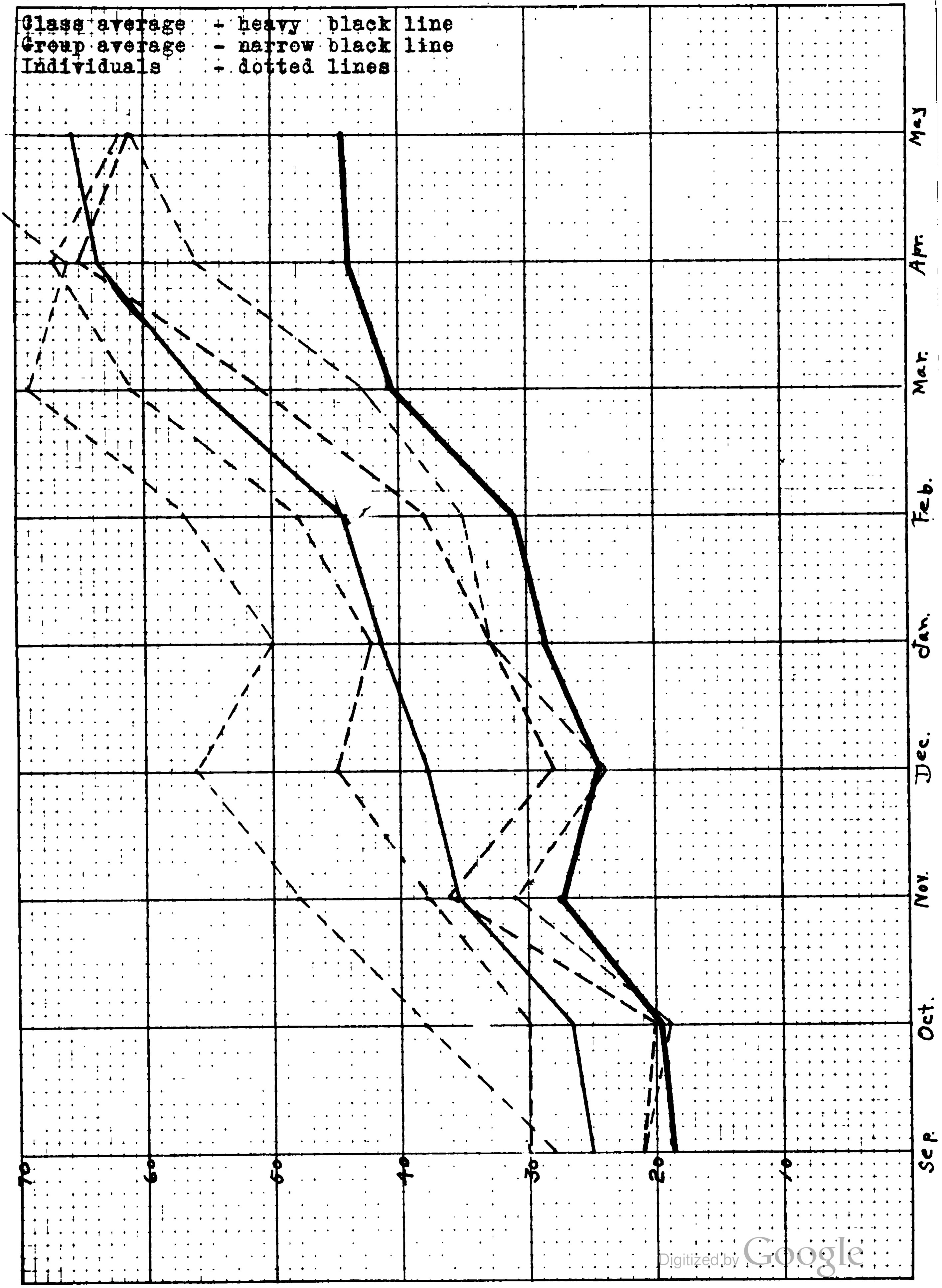


Class average - heavy black line
Group averages

Grade VI
FORM C3

PLATE II

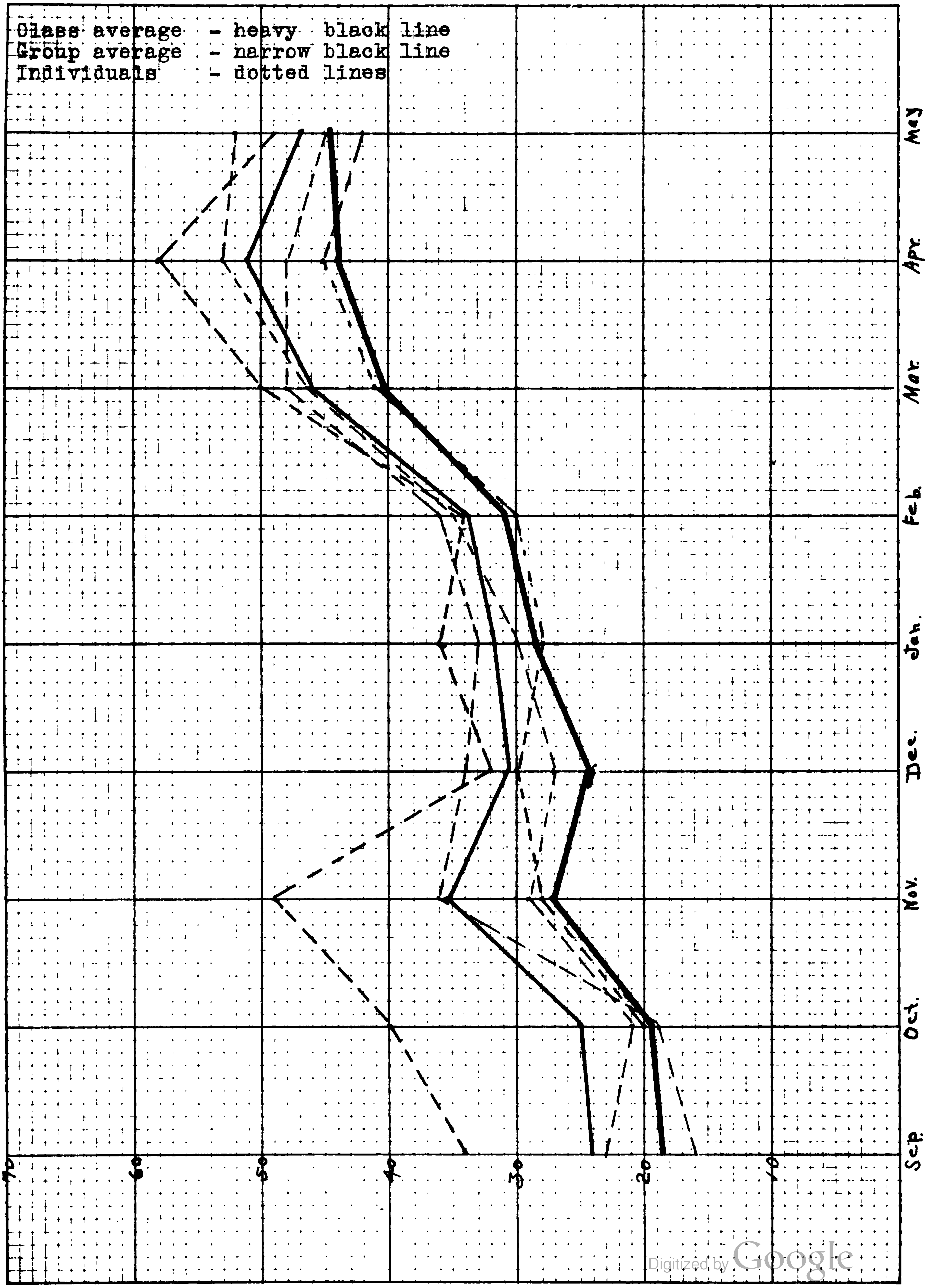
UNIVERSITY OF WISCONSIN



Class average - heavy black line
Group average - narrow black line
Individuals - dotted lines

Grade VI PLATE III

FORM C3 UNIVERSITY OF WISCONSIN



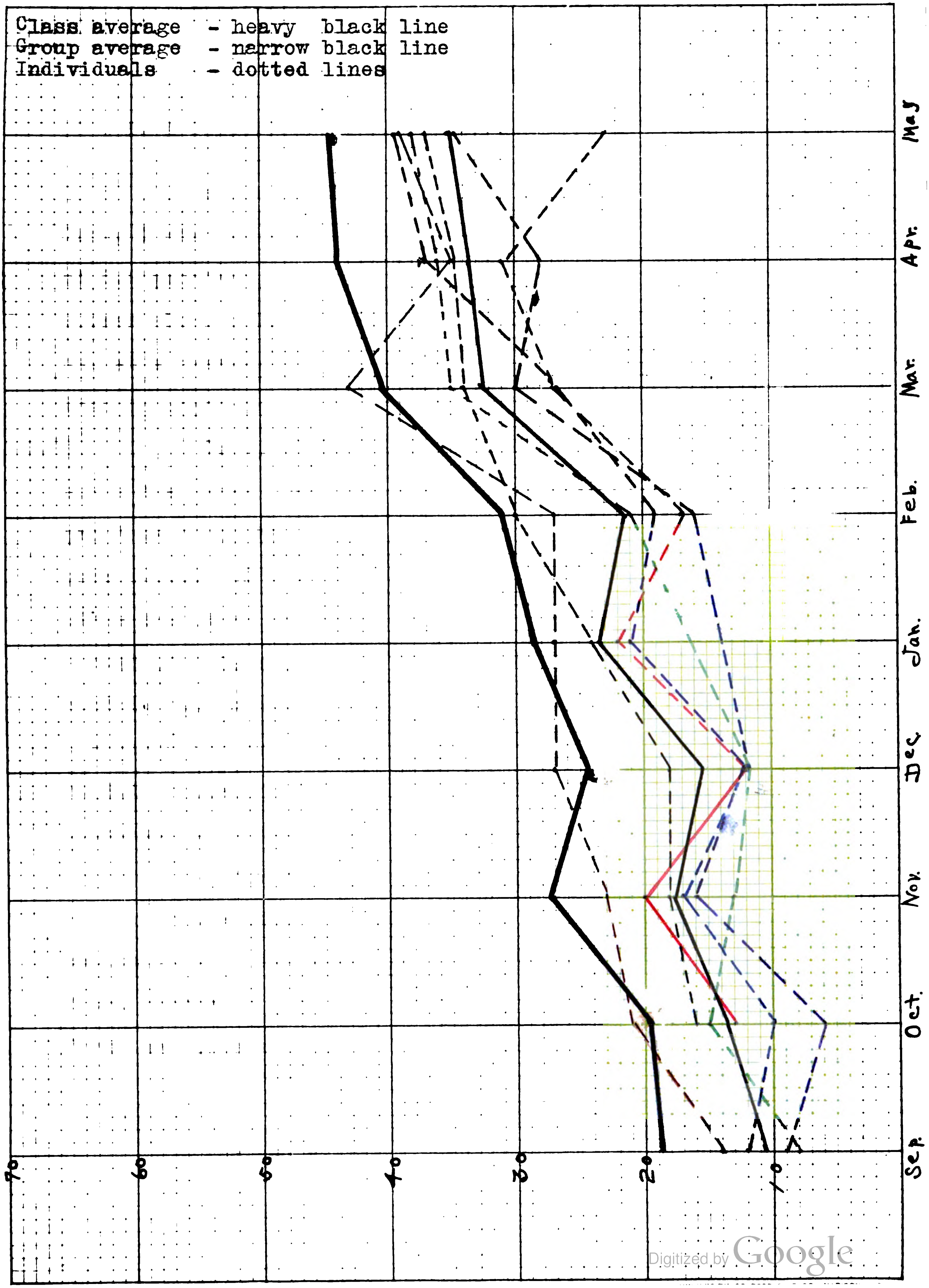
Class average - heavy black line
Group average - narrow black line
Individuals - dotted lines

Grade VI

PLATE IV

FORM C3

UNIVERSITY OF WISCONSIN



Class average - heavy black line
Group average - narrow black line
Individuals - dotted lines

GRADE VI.

Interpretation of Material.

I. A Comparison of Group and Class Performances.

A comparison of the initial performances of Group I with that of the entire class shows a difference of 6.2 problems. A similar comparison of the final scores shows a difference of 21.2 problems. Thus Group I was at a greater distance from the class average in May than in September by 15 problems.

Group II begins the year's work 5.5 problems above the class average, and ends the school year at 2.5 problems above the class average. This group during the year approached nearer the class average by 3 problems. Since the class is divided into three sections, Group II should closely represent the class performance, and the monthly scores show that the maximum difference between the class performance and the performance of Group II to be 8.1 problems while it is less than 3 problems during 2 consecutive months.

A comparison of Group III with the class average shows that the initial difference in the September scores is 8.1 problems, and a similar comparison in their final scores in May is 9.4 problems, i.e. Group diverged from the class average by 1.3 problems.

SUMMARY

The two extremes, Groups I and III, diverge

more from the class average in May than in September. This divergence increases considerably thruout the year, and is particularly marked in the last 4 months. The middle, Group II, representative of average class accomplishment, adheres closely to the class performance and tends rather to approach the class average as the school year advances. The curves of improvement present similar characteristics to grades IV and V. Greatest gain is at the close of the year.

II. A Comparison of Groups.

Group I.

The difference in the initial scores of Group I and II is .7 problems, and the difference in their final scores is 18.7 problems, i.e., Group I increased its lead over Group II by 18 problems during the year. A similar comparison of Group I and III shows an initial difference in scores of 14.3 problems and a final difference in scores of 30.6 problems, or that Group I increased its lead over Group III by 16.3 problems. Thus Group I diverged from each of the other two Groups by 11.8 and 16.3 problems respectively.

Group II.

Group II diverged negatively from Group I by 11.8 problems, and converged in respect to Group III by 1.7 problems.

Group III.

Group III during the year's work diverged from Group I by 16.3 problems and approached nearer to Group II by 1.7 problems. The extreme Groups have tended to diverge considerably with a year's practice.

A comparison of the intial and final scores of the various Groups shows that Groups I and II, and also Groups I and III diverge considerably during a year's practice period. Groups II and III show divergence at the close of the eighth month, however in the final month Group II makes a final negative accelleration and, consequently, these two Groups show a slight convergence of 1.7 problems at the close of the session. The Group with the highest initial score made the largest gross gain. The Group with second highest initial score was surpassed by the Group below it by 1.7 problems. This is due to the fact that the Group with the second highest initial score experienced a marked negative accelleration in the final score. Since this Group has made consistent gains previous to this final negative acceleration the April score is a truer index of its capacity. By taking the eighth month as the final record which seems a reasonable procedure, Group II with the second highest initial score registers the second greatest gross gain, and Group III with the lowest initial score makes the least gross gain.

The progress of each Group has been along fairly definite, divergent lines, and the efficiency of the several Groups has tended to widen by a year of study.

The wide range of accomplishment between Groups I and III would justify a re-classification also of this grade though its need is not as urgent as in grade IV and V.

A Comparison of Individuals.

Group I.

The maximum individual difference in the initial period between members of Group I is 9 problems, and the maximum final difference is 18 problems. This indicates that the individual members of the select Group tend to diverge by a year of training. The same tendency, then, maintains among individual members in the select Group as among the Groups themselves. However, this divergence in the select Groups is considerably reduced and the individual members remain together within definite boundaries. All members of the Group begin the year above the class performance and remain constantly above it throughout the year (with a single individual exception) and establish final scores far in excess of the class average.

Group II

The maximum initial difference between members of Group II is 18 problems, and the maximum final difference is 10 problems, i.e. the members of Group II show a convergence of 8 problems. One member of this Group has a September score of 34 problems, an October score of 40 problems, a November score of 49 problems, and in the next three months 32, 36, and 34 problems respectively, i.e. after 6 months this individual has the same score as recorded in the initial test. Consequently, his unusually high initial score of 34 problems (which is the highest in the entire class including Group I) does not appear to represent his true initial rating. If this initial score is advanced to December when this individual gets his bearings, this Group will also show the characteristic tendencies of slight divergence by 3 problems. In general the members of this Group remain within a zone of relatively narrow limits.

Group III.

The maximum individual difference between members of Group III is 6 problems, the maximum final difference is 16 problems. Since two members are not represented in the initial test, the second month serves as a truer index of the several efficiencies of this Group. However, in either case the individual members diverge in ability by a year of training.

General Summary for Grade VI.

1. The extreme Groups tend to diverge much more widely from the average of the class performance at the close of the practice period than at the beginning.
2. The curves widen out in a fan shape and this deviation from the average is most marked in the extreme Groups.
3. The Group with the highest initial score has made the largest gross gain. Group II with the second highest initial score makes the smallest gross gain, and Group III with the lowest initial score makes the second highest gross gain. There are three absences in the initial score in Groups II and III and by shifting the initial score to October when all members are present, Group II then comes second and Group III last in the gross gain.
4. Each Group pursues a fairly definite course and the distances between the Groups increase during the year.
5. Brightest pupils apparently profit most, while the average pupils seem to profit least.
6. The average number of negative accelerations of the three Groups is as follows: Group I, 2¼; Group II, 2¾; Group III, 2;
7. A single pupil passed through the year without a negative acceleration but was absent on one test.
8. The divergence between the Group and the class average tends to increase constantly throughout the year, and

this divergence is more evident in the final three months of the year.

9. The highest Group makes the greatest gain, and the lowest Group the smallest gain relatively to the class average.

General Summary.

1. The several groups in the respective classes show tendencies to diverge by a year of practice.

2. The divergence of the group is especially marked in the last third of the year's work.

3. The individual members within a group also show marked tendencies to diverge with practice, though this divergence is relatively slight.

4. Groups with the highest initial score have made the greatest gross gain.- i.e., the brightest students apparently profit most and backward students profit least.

5. If we assume that the practice periods were uniform and the amount of outside work was constant for all the individuals, the above results seem to indicate that this increase in the differences of individuals is due to native endowment.

GENERAL CONCLUSIONS.

This study confirms for more complex abilities what has been found by Thorndike and others that individual differences tend to increase rather than to decrease by equal practice. The curves of improvement show increasing divergence throughout the entire school year. The rate of improvement is particularly marked in all of the grades during the last three months with a slow steady rise and gradual divergence during the first six months. When the classes are subdivided into groups on the basis of initial performance the group with the highest initial average gains most absolutely and in most cases relatively. The lowest group in each grade makes very little absolute gain and a very considerable relative loss. The same general principle holds for the individuals within each of the groups. So far as the improvement of the class as a whole then throughout the year is concerned it is due essentially to the very great improvement of the better pupils. This has a very considerable bearing on the application of standard scores where standard tests are employed for the measurement of individuals. From a theoretical point of view the results are a pretty clear indication that improvement is very largely a matter of native endowment rather than amount of training. Since individual differences tend to increase so markedly rather than to be reduced by equal training the differences initially could not have been due to varying amounts of

previous training. An inspection of the plates shows very clearly throughout that individuals tend to maintain the same relative stations throughout the year. There is little evidence of any marked shifting or fluctuation in stations such as one might possibly expect. The correlations have not been worked out numerically though this could have been done. It will be a matter of considerable interest and importance to determine how far improvements in other school subjects follow the same general laws as appear to hold here for the four fundamental operations in Arithmetic. There is little evidence bearing on this point but a general inspection of similar records throughout the year in rate of reading and comprehension, in Spelling and Handwriting.

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APPROVED:

VAC Henmon
Professor of Education

June 14 1917.

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